PATENT SPECIFICATION

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Int. Cl.:— B 29 d // B32b, C08f.

COMPLETE SPECIFICATION

DRAWINGS ATTACHED

Lightweight Constructional Elements

We, HAMBURGER FLUGZEUGBAU G.M.B.H., a German Company, of 10 Kreetslag, 2103 Hamburg-Finkenwerder, Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention concerns a method of making lightweight constructional elements.

It is known to manufacture lightweight constructional elements, such as panels, aeroplane fuselage parts, and the like, in the form of a layered structure or a sandwich-type structure, composed of an inner compartmented filling of a compression-resistant type faced on opposite sides with strong surface laminae or skins. These constructions are subject to a number of disadvantages. In the aircraft industry, for example, it is necessary for the compartments of the inner filling to be open to the atmosphere outside the constructional element, so as to avoid changes in pressure differential between the outside of the element and the interior of the compartments due to change in altitude of the aircraft in which the element is incorporated. This has the effect of promoting condensation within the elements which, in turn, results in undesirably high corrosion of the material of the element, particularly if it is of metal. Furthermore, good bonding of the surface laminae or skins to the compartmented filling is technically difficult and after the constructional elements have been completed it is extremely difficult, and sometimes completely impossible to check that the laminae or skins are, in fact, properly fastened to the filling. Moreover, such constructions, which generally employ a honeycomb type of filling, are not usually sufficiently dimensionally stable for general aircraft use.

To try to obviate these disadvantages, a method of making a structure wherein the compartments are filled with a foamed plastic has been proposed. With this structure condensation corrosion is reduced and the rigidity of the structure is improved, but the weight of the elements is increased considerably, and there are practical difficulties involved in the actual introduction of the foamed plastic into the compartments of the panel.

The present invention proposes a method of making a structure which differs materially from those hitherto employed, and according to the present invention there is provided a method of making a lightweight constructional element which comprises arranging, in a mould or former of shape corresponding to the desired overall external shape of the constructional element, a plurality of rigid spheres, so that the spheres are close to one another and, securing the spheres relative to one another, without application of extraneous pressure, at least at their confronting surfaces or points of contact by an adhesive or binder, so that the adhered-together spheres constitute a coherent mass.

For use in environments where they are likely to be only lightly stressed, there is proposed a method of making an arrangement of the element wherein the adhesive or binder does not completely fill the interstices between the spheres, so that there are air pockets between the spheres.

In such an arrangement there may or may not be surface or facing laminae, according to the use to which the element is to be put.

On the other hand, for use in locations where they are likely to be subjected to considerable stresses a preferred embodiment of the element made by the method

is an arrangement wherein the adhesive is plastic foam which occupies the interstices between the spheres of the coherent mass, and wherein the coherent mass is sandwiched between two facing laminae or skins, which skins may, additionally, if desired be kept separated from one another by tube-like spacers extending through the interstices between the spheres.

Arrangements between these two extreme arrangements are, of course, possible.

We have found, by tests and comparisons, that the use of spheres in the manner of the invention, in making lightweight constructional elements, has considerable advantages. For example, an element composed of table tennis balls embedded in a matrix of foamed plastic, and having no facing lamina or skin, had a resistance to compression between three and four times that of a comparable honeycomb sheet.

If thin-walled hollow metal spheres are used, considerably better resistance to compression and bending forces is achieved.

The method of the invention, using the coherent mass of spheres, is suitable for all fields requiring the use of lightweight structural or constructional elements. Thus, it is applicable not only to flat panels or sheets, but can be used in moulding bodies of all kinds, such as wing-tip edges on aircraft wings, radomes and aircraft tailplanes, and facilitates the production of such parts. By appropriate selection of the sizes, wall thicknesses and materials of the spheres and corresponding selection of the binder or adhesive (which may be a foamable plastic, or simply a non-foaming plastic or other material which will stick, bond or secure the spheres firmly to one another) constructional elements of diverse strengths and weights can be produced, according to any specific requirements. Further, where the interstices between the spheres are filled with the adhesive or binder, good heat and sound insulation are achieved as well as good corrosion, temperature and pressure resistance.

The invention will be described further, by way of example, with reference to the accompanying drawings, in which:—

Fig. 1 is a part-sectional plan of a preferred embodiment of a constructional element made according to the present invention;

Fig. 2 is a cross-section taken on the line II-II of Fig. 1;

Fig. 3 is a part-sectional perspective view of the element of Figs. 1 and 2;

Fig. 4 is a part sectional plan view of a second embodiment of constructional element made according to the invention;

Fig. 5 is a cross section taken on the line V-V of Fig. 4;

Fig. 6 is a part-sectional plan view of a third embodiment of constructional element made according to the invention;

Fig. 7 is a cross-section taken on the line VII-VII of Fig. 6;

Fig. 8 is a part-sectional plan view of a fourth embodiment of constructional element made according to the invention;

Fig. 9 is a section taken on the line IX-IX of Fig. 8;

Fig. 10 is a diagrammatic cross-sectional side elevation showing a moulded part made according to the invention;

Fig. 11 is a perspective view, to a reduced scale, of the body of Fig. 10;

Fig. 12 is a diagrammatic cross-sectional side elevation illustrating a first stage of a method of producing constructional elements, such as the element of Figs. 1 to 3, in accordance with the invention;

Figs. 13, 14, 15 and 16 are all views similar to Fig. 12, but illustrating successive steps in producing the constructional element, Fig. 16 showing the finished product;

Fig. 17 is a diagrammatic part-sectional side elevation, on a reduced scale, illustrating a method of producing the moulded body of Figs. 10 and 11 in accordance with the invention; and

Fig. 18 is a diagrammatic part-sectional side elevation illustrating another method of producing a constructional element in accordance with the invention.

Referring firstly to Figs. 1 to 3, a preferred embodiment of constructional element made according to the method of the invention, which in this instance is in the form of a panel, comprises a plurality of hollow spheres 1 which are arranged so as to lie close to one another and generally to define the overall shape of the constructional element. In this embodiment the element, being a flat panel, comprises a single layer of spheres 1 of equal outside diameters, arranged in rows and columns, but it will be appreciated that two or more layers of spheres of equal sizes could equally well be used, as also could an element comprising spheres of different sizes provided the overall arrangement thereof conforms to the desired panel dimensions.

The spheres 1 are located relative to one another in the desired shape of the constructional element by being embedded in foamed plastic 2 which serves as a matrix or binder, the adhered-together spheres constituting a coherent mass. Such plastic (which may for example be foamed polyurethane, foamed polystyrene or any other suitable foamed synthetic resin) serves also to bind, to the coherent mass of spheres 1, so that the latter is sandwiched therebetween, a pair of facing laminae or skins 3 which may be of any suitable sheet material such as light metal, laminated

wood or plastic.

The spheres 1 can be of plastic or of metal, and it will be appreciated that by selection of appropriate materials for the spheres, for the facing laminae or skins and for the foamed plastic matrix, panels whose strength, bending resistance and compressibility conform to diverse specific requirements can be obtained.

Since plastic foams of considerable strength are now available, it is quite practicable for a constructional element made according to the invention to have no facing laminae or skins. Such an arrangement is shown in Figs. 4 and 5, and comprises solely the coherent mass of spheres 1, in a single layer, bound together by a matrix of foamed plastic 2 which occupies all the interstices between the spheres 1 and provides plane outer surfaces for the element. The exposed surfaces of such a plastic matrix can, if desired, be treated, e.g. by metal spraying to strengthen the element.

In Figs. 4 and 5, the spheres 1 are arranged in rows which are staggered so that the spheres of each row fit snugly into the recesses between the spheres of the adjacent row or rows. It will be appreciated, however, that the row and column arrangement of Fig. 1 can equally well be employed in this embodiment.

Figs. 6 and 7 show a modification of the embodiment of Figs. 4 and 5 in that facing laminae or skins 3 are provided on the element and, additionally, embedded in the matrix of foamed plastic 2 are a plurality of tubular spacers 4 each of axial length equal to the outside diameters of the spheres 1. These spacers extend through the interstices between adjacent spheres 1 and serve to assist the matrix in preventing movement of the surface laminae or skins 3 towards one another in the regions of the interstices between the spheres 1, e.g. when the constructional element is subjected to compressive stress.

Referring now to Figs. 8 and 9, these figures illustrate an elementary form of the constructional element made according to the invention. This is cheap to produce and can be employed in environments where it is unlikely to be subjected to stresses, or is likely only lightly to be stressed, for example in partitions, room doors, lightweight containers and similar uses.

In this embodiment, the spheres 1 of the coherent mass are arranged in columns and rows as in the example of Figs. 1 to 3, but instead of the interstices between the spheres 1 being occupied by a foamed plastic, the spheres are simply connected to one another by adhesive or bonding material, e.g. in the form of a non-foaming synthetic resinous adhesive 5 between the facing surfaces of the adjacent spheres or between and around the points of contact of the spheres. The adhesive 5 also serves, in this embodiment, to bond the laminae or skins 3 to the coherent mass of spheres 1, but it will be appreciated that in certain applications (e.g. where the constructional element is intended as a packing insert in a crate or the like) one or both of the facing laminae or skins 3 may be omitted. Of course, the arrangement of the spheres 1 in the coherent mass can differ from that shown, and a number of layers or a mass of spheres of different sizes conforming to the desired three dimensional shape of the constructional element can be used.

Figs. 10 and 11 show an example of a constructional element made according to the method of the invention which is in the form of a moulded body intended for use as a radome. In this case, the coherent mass comprises spheres 1 embedded in a matrix of foamed plastic 2, but no facing laminae or skins are provided.

As shown, the coherent mass of spheres is arranged in a three-dimensional shape corresponding approximately to a paraboloid of thickness equal to the outside diameter of one sphere, all the spheres being of the same size. One way in which this constructional element may be made will be described later.

Referring now to Figs. 12 to 16, these figures illustrate one suitable method of producing the constructional element of Figs. 1 to 3, and a similar procedure can be employed in relation to the panel of Figs. 4 and 5. Firstly, the spheres 1 are appropriately arranged in a mould which comprises a base board 6 whereon are arranged side walls 7 having slots or apertures 10 therein. Thereupon, a previously-prepared fluid foam-plastic mix, which has not commenced foaming or has not yet fully foamed, is poured into the mould, and a top board or lid 9 is applied across the sidewalls 7 as shown so that the interior of the mould is open to the outside only through the slots or apertures 10. It will be observed that the height of the sidewalls 7 is substantially equal to the outside diameters of the spheres so that the undersurface of the top board or lid 9 will either just contact the spheres 1 or will be spaced away therefrom only by a very small distance, e.g. of the order of one or two millimeters.

Expansion of the foam-plastic mix within the mould causes the interstices between the spheres 1 to become wholly occupied by plastic foam, and excess of the mix is employed to ensure this, the continued expansion of the mix until foaming is completed resulting in excess foam being expressed from the mould by way of the slots or apertures 10, as shown in Fig. 14. When foam-

ing is completed, the plastic is a matrix in which the spheres are embedded and the sidewalls 7 are removed (as shown in Fig. 15) and the top and boards 9 and 6, which will be stuck, bonded or secured to the matrix are trimmed to correspond with the edges of the matrix as shown in Fig. 16. The top and bottom boards 9 and 6 of the mould accordingly constitute the surface laminae or skins of the finished constructional element, and consequently they can be of appropriate material, such as light metal, plastic sheet or board, hardboard or timber. No extraneous pressure is applied to the mould during the moulding process.

Obviously, where the constructional element is to have only one surface lamina or skin, or no surface laminae or skins are required, the mould will be such that the top and/or bottom boards will not adhere to the matrix. This can be done, for example, by coating the relevant board with a release agent, such as a silicone, or by the use of boards to which the matrix will not adhere to the matrix. This can be done, for example, by coating the relevant board with a release agent, such as a silicone, or by the use of boards to which the matrix will not adhere.

The embodiment of the invention shown in Figs. 6 and 7 can be produced in a similar way but the tubular spacers 4 will be positioned between the spheres before the foam-plastic mix is introduced into the mould.

Fig. 17 shows an example of how the moulded body of Figs. 10 and 11, and similar moulded bodies, can be produced. In this instance, use is made of a shaped or contoured mould composed of an outer or female part 12 pierced by holes at intervals (which holes are considerably smaller than the spheres) and a hollow inner or male part 13 having apertures 15 which are larger than the holes in the female part but are still smaller than the spheres. The latter are appropriately arranged between the two mould parts, whereupon a quantity of foam-plastic mix is poured into the interior of the male mould part 13. The mix is then forced into the space between the two mould parts by introducing a ram or piston 14 of appropriate shape into the interior of the male mould part 13 as indicated by the arrow in Fig. 17. Expansion of the plastic mix, during foaming thereof, causes the interstices between the spheres to become filled with the foamed plastic, and, as with the previous example, excess of such plastic can escape through the apertures in the female mould part 12.

After setting of the plastic foam, the mould parts are separated from the foamed plastic matrix to result in the moulded body of Figs. 10 and 11, but if surface laminae or skins are required on the body, one or both of the mould parts can be caused to adhere to the matrix.

Fig. 18 illustrates a method of producing a moulded body one surface of which is substantially flat and the other surface is contoured, so that the general shape of the body somewhat resembles a plano-convex lens. In this instance, use is made of a former 16 of shape corresponding to the desired shape of the contoured surface of the eventual structural element, and firstly a lower layer of spheres 17 of equal sizes is arranged over such former as shown. Thereupon, foam plastic mix containing a large number of hollow spheres 18 of various sizes, all smaller than the spheres 17 is poured into the former, so that such spheres 18 become arranged in and occupy the rest of the space in the former 16 above the layer of spheres 17 and the plastic mix enters the interstices between all the spheres. Expansion of the mix due to foaming ensures that such interstices become substantially wholly filled with foamed plastic, and excess of the latter can, of course, overflow the former 16 and be readily removed. When foaming is finished, the upper surface of the matrix formed by the foamed plastic can be smoothed off, and the plastic is then allowed to set.

As in the preceding examples, the former 16 can be caused to adhere to the matrix to provide a surface lamina or skin on the finished constructional element but it can be removed and re-used if desired. Similarly, it would be possible to provide a lid (which is either stuck to the matrix or removed after completion of setting of the foam) across the former, provided appropriate provision is made for excess foam to escape from the former.

It is not essential, of course, for the spheres to be arranged firstly in a layer of equal sized spheres 17 before the spheres 18 of various sizes are introduced, and it would, naturally, be possible simply to fill the former with the spheres 18, so that the arrangement of the different sizes of spheres within the former can be at random, so long as they together constitute a coherent mass whose general shape conforms to the desired three-dimensional shape of the finished constructional element, being eventually fixed relative to one another in such arrangement by the plastic whether this merely be an adhesive which simply locates the spheres in their respective relative positions or whether it be a foamed plastic material wherein the spheres are embedded.

Obviously, the same considerations apply to the previous embodiments. The spheres can be in carefully positioned layers and of selected sizes, or they can be of various sizes randomly introduced with the mould

or former to fill the latter.

The surfaces of the body can be metallised, if desired.

WHAT WE CLAIM IS:—

1. A method of making a lightweight constructional element which comprises arranging, in a mould or former of shape corresponding to the desired overall external shape of the constructional element, a plurality of rigid spheres, so that the spheres are close to one another and, securing the spheres relative to one another, without application of extraneous pressure, at least at their confronting surfaces or points of contact by an adhesive or binder, so that the adhered-together spheres constitute a coherent mass

2. A method as claimed in claim 1, wherein the mould or former has apertures through which excess adhesive or binder can escape.

3. A method as claimed in claim 1 or 2, wherein the mould or former comprises a single panel to which the coherent mass becomes connected by the adhesive or binder, so as to constitute a facing lamina or skin thereon.

4. A method as claimed in claim 1 or 2 wherein the mould or former comprises two panels, the adhesive or binder causing the panels to be attached to the coherent mass to constitute facing laminae or skins thereon.

5. A method as claimed in any of claims 1 to 4, wherein the adhesive or binder is a foamable plastic which serves to occupy the interstices between the spheres and thereby constitute a matrix in which the spheres are embedded.

6. A method as claimed in claim 5, wherein the matrix does not completely fill the interstices between the spheres, so that there are air pockets between the spheres.

7. A method as claimed in claim 5 or 6, wherein the adhesive or binder and the spheres are introduced into the mould by pouring simultaneously.

8. A method as claimed in claim 5 or 6, wherein the foamable plastic is caused to foam during or after its introduction between the spheres.

9. A method as claimed in any preceding claim, wherein the spheres are of equal outside diameters.

10. A method as claimed in any of claims 1 to 8, wherein the spheres are of various diameters.

11. A method as claimed in claim 9, wherein the coherent mass comprises a single layer of spheres.

12. A method as claimed in claim 4 or any claim appendant thereto, wherein tubular spacers, of axial length substantially equal to the outside diameters of the spheres, are provided between the skins, the spacers extending through the interstices between adjacent spheres.

13. A method as claimed in claim 10, wherein the coherent mass comprises a single layer of spheres, all of the same outside diameter, next to which is a layer of spheres of different diameters.

14. A method of making a lightweight constructional element substantially as hereinbefore described with reference to and as illustrated in Figs. 12 to 16, Fig. 17 or Fig. 18 of the accompanying drawings.

15. A lightweight constructional element made by the method claimed in any preceding claim.

For the Applicants,
BARLOW, GILLETT & PERCIVAL,
Chartered Patent Agents,
94 Market Street, Manchester, 1,
and
20 Tooks Court, Cursitor Street,
London, E.C.4.

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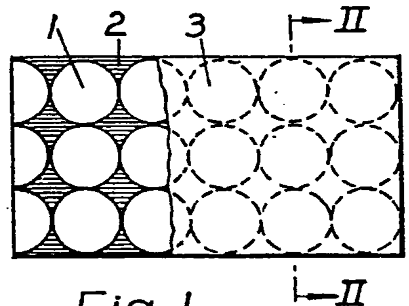


Fig. 1.

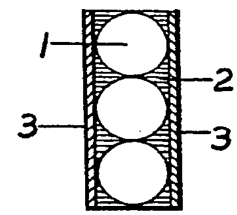


Fig. 2.

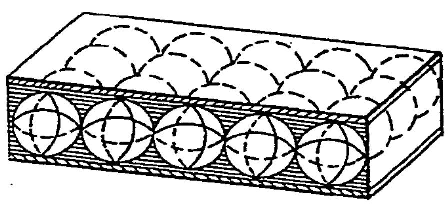


Fig. 3.

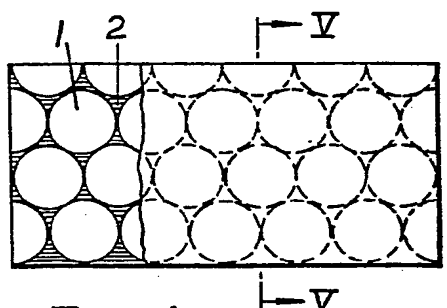


Fig. 4.

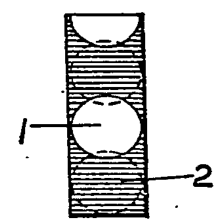


Fig. 5.

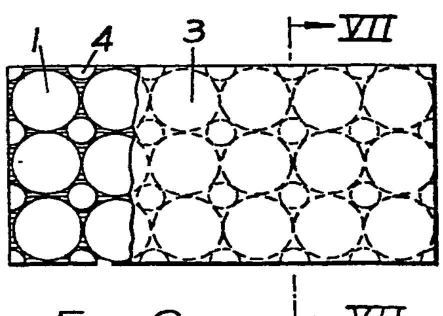


Fig. 6.

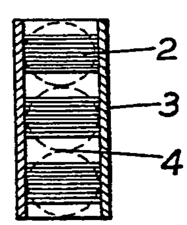


Fig. 7.

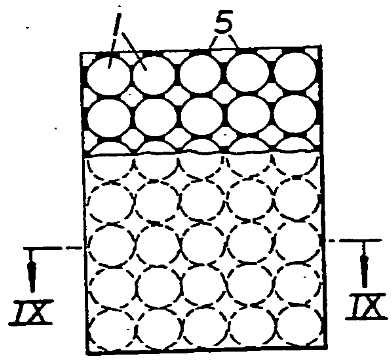


Fig. 8.

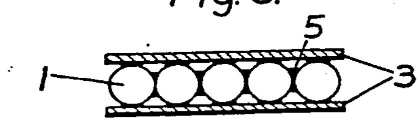


Fig. 9.

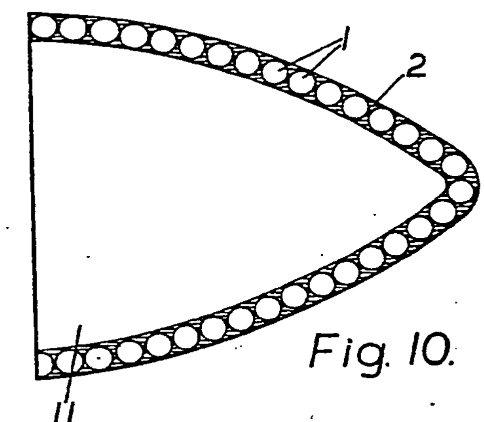


Fig. 10.

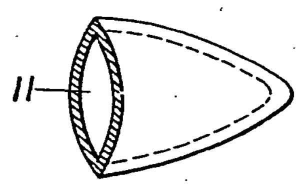


Fig. 11.

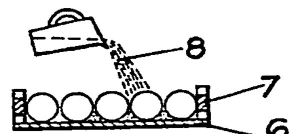


Fig. 12.

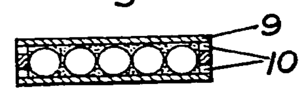


Fig. 13.

Fig. 14.

Fig. 15.

Fig. 16.

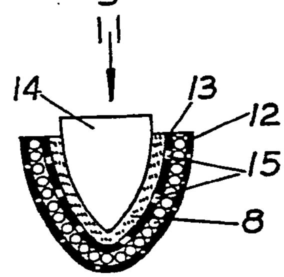


Fig. 17.

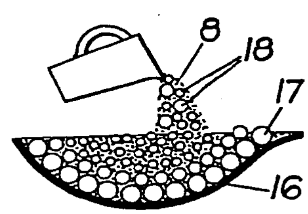


Fig. 18.

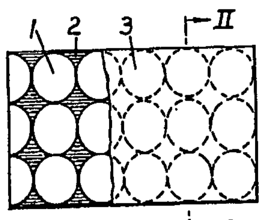


Fig. 1.

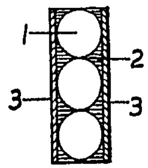


Fig. 2.

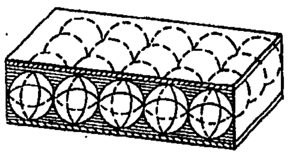


Fig. 3.

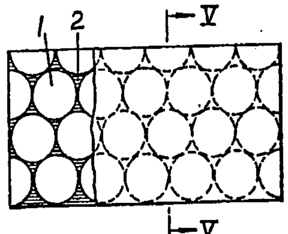


Fig. 4.

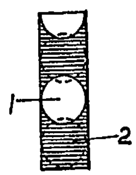


Fig. 5.

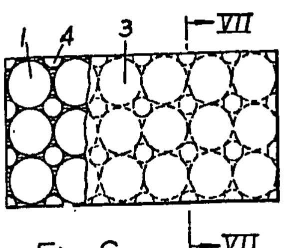
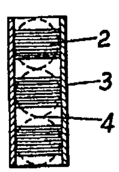


Fig. 6.



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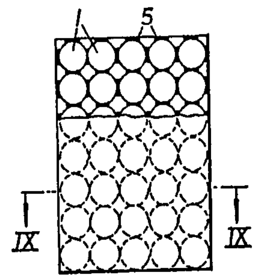


Fig. 8.

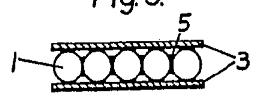


Fig. 9.

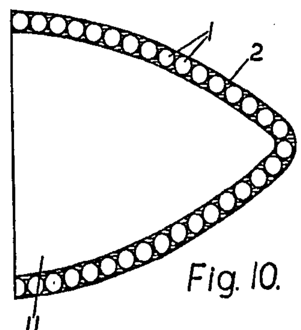


Fig. 10.

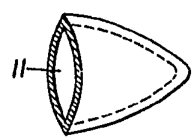
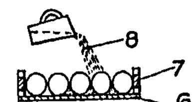


Fig. 11.



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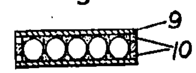

Fig. 13.

Fig. 14.


Fig. 15.


Fig. 16.

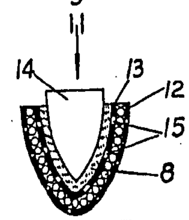

Fig. 17.

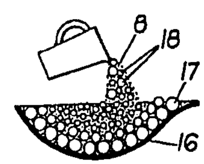

Fig. 18.